

SPASM

Sketch Planning Analysis Spreadsheet Model

User's Guide

September 30, 1998

1.0 Introduction

This document describes Cambridge Systematics' Sketch-Planning Analysis Spreadsheet Model (SPASM). The model has been developed to assist planners in sketch-planning analyses of packages of transportation actions at the system and corridor level, including:

- Transit system improvements
- Highway capacity improvements
- HOV improvements
- Auto use disincentives
- Combinations of the above actions

SPASM, which is currently implemented in both EXCEL and LOTUS 123, provides estimates of the following measures of effectiveness for proposed actions:

- Benefits and costs to transportation system users
- Annualized cost to public agencies
- Effect on total transportation cost
- Change in emissions for hydrocarbons, carbon monoxide, and nitrogen oxides
- Change in energy use

The model takes the following effects into account:

- Discounting of costs and benefits over time
- Congestion-related effects of changes in vehicle miles of travel on speeds during peak and off-peak periods
- Diversion of traffic among parallel highway facilities in a corridor
- Induced (or disinduced) traffic occurring as a result of changes in highway congestion levels
- Effects of speed and cold starts on motor vehicle emissions and fuel consumption
- Benefits to travelers resulting from increased trip-making due to travel time and costs savings

The model user provides estimates of the initial effects of the actions on highway capacity, travel costs, and travel demand for five modes of transportation (automobile, truck, carpool, bus, and rail). The spreadsheet then calculates effects on highway speeds and subsequent changes in highway usage related to these speed effects.

The rest of this User's Guide is organized as follows:

- Chapter Two describes the analytical procedures used in the model
- Chapter Three provides a general overview of the organization of the spreadsheet implementing the model and defines spreadsheet inputs and outputs
- Chapter Four provides sample applications of the model

2.0 Analytical Procedures

This chapter describes analytical procedures that are used in the spreadsheet for:

- Annualization of capital costs
- Analysis of consumer surplus
- Congestion analysis
- Induced traffic analysis
- Emissions analysis
- Fuel consumption analysis

Annualization of Capital Costs

In the spreadsheet, benefits and costs are estimated for an analysis year. To determine capital costs for the analysis year, total capital costs are converted into a stream of annual costs started in the year of opening and extending over the useful life of the project. For simplicity in this conversion, all capital costs are viewed as incurred in the year entered by the spreadsheet user as the midpoint of the construction period. The equation used to annualize capital costs is as follows:

$$a = \frac{(1-r)}{(1-r^L)} \frac{C}{r^{y_o-y_m+1}}$$
$$r = \frac{1}{1+d}$$

where:

- C is capital cost;
- y_o is the year of opening;
- y_m is the midpoint of the construction period;
- L is the useful life of the investment in years;
- d is the discount rate expressed as a fraction (e.g., 0.07); and
- a is capital cost annualized over the useful life of the investment.

Analysis of Consumer Surplus

The spreadsheet uses the concept of consumer surplus to estimate: (1) the benefits to new transit users of transit improvements; (2) the benefits to new carpool users of carpool incentives; (3) the disbenefits to auto users of auto use disincentives; and (4) the benefits to new auto users of highway capacity improvements. Consumer surplus is illustrated in Exhibit 1; the shaded triangular area is equal to the benefits to new trip-makers due to the fact that the cost per trip that they are required to pay is less than the maximum cost per trip that they would be willing to pay. In the spreadsheet, the area of the triangle is approximated as the increase in the number of trips times the decrease in the cost per trip divided by 2.

Congestion Analysis

The effects of increases or decreases in VMT on highway speeds are estimated using the following equation:

$$S_{av} = \frac{1}{1/S_{ff} + a(V/C)^b}$$

where:

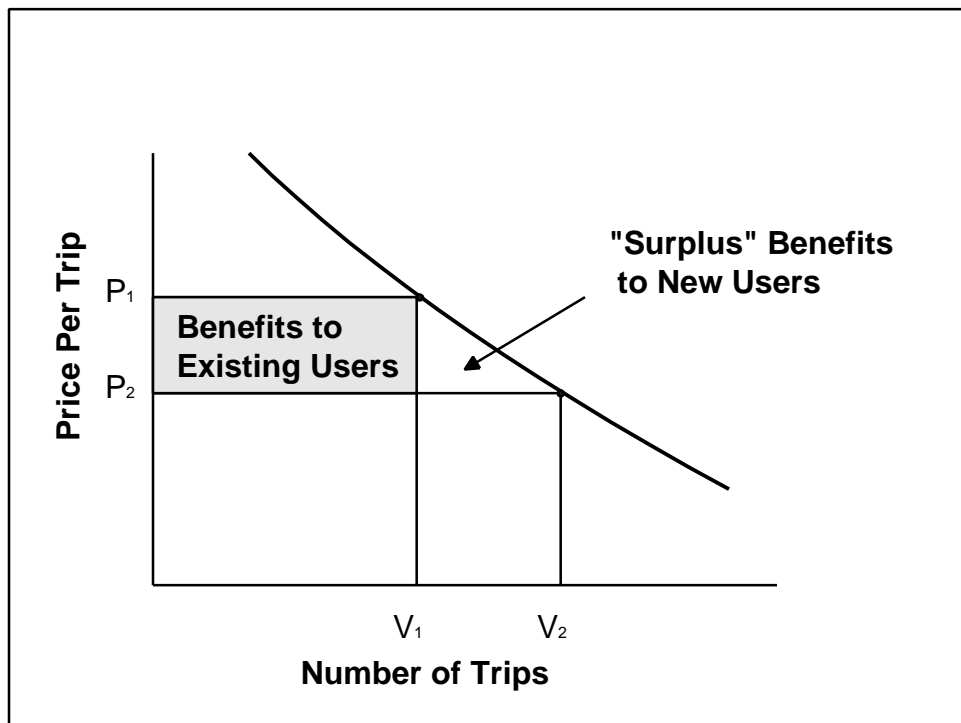
- S_{av} is average speed
- S_{ff} is free-flow speed
- V/C is the volume-to-capacity ratio
- a and b are model parameters

The values of a and b currently used for the peak and off-peak periods are based on results from a recently completed study conducted by Cambridge Systematics for FHWA. It incorporates the effect of recurring congestion on speeds through the volume-to-capacity ratio. However, it does not incorporate additional delay due to incidents such as stalled vehicles or crashes. Cambridge Systematics is currently conducting another study to incorporate the effects of incidents in speed-volume relationships. When that research is completed, speed-volume relationships that incorporate the effects of incidents will be used.

Diversion Analysis

The diversion of traffic among parallel highway facilities in a corridor is modeled by assuming that traffic will distribute itself among these facilities in proportion to the travel time on each

Exhibit 1
Consumer Surplus



facility raised to a power specified by the model user. The spreadsheet uses an iterative process for diversion analysis. Initially, traffic is distributed among facilities in proportion to their zero volume speeds. Updated speeds are then calculated based on the distribution of traffic from the previous iteration. This process continues until the spreadsheet convergence criteria is satisfied.

Induced Traffic Analysis

The analysis of induced traffic and its effects on speeds are developed using estimates of the elasticity of travel demand with respect to travel time (which is input by the spreadsheet user) and the congestion analysis equations presented above. The elasticity of demand is defined as the percentage change in traffic due to a one percent increase in travel time.

Specifically, the spreadsheet performs the following steps:

- Develop an initial estimate of travel time savings (in percentage terms) due to the actions under consideration based on "before" and "after" volumes and capacities provided by the model user.
- Develop an initial estimate of induced traffic using time savings and the elasticity of demand.
- Recalculate travel time savings, accounting for the additional delay caused by induced traffic
- Recalculate induced traffic, using the revised estimate of travel time savings
- Repeat the two preceding steps until travel time savings and induced traffic don't change significantly from iteration to iteration.

Emissions Analysis

In our revised Sketch-Planning Spreadsheet, emissions for autos, trucks, carpools, and buses are calculated as the sum of

- Emissions on each highway system segment (calculated under the assumption that vehicles are already warmed up)
- Added emissions due to cold starts

Emissions on highway system segments are calculated using emission rates as a function of speed. Specifically, emission rates are input for speeds of 5, 10, 15, ..., 60, and 65 miles per hour, and the spreadsheet interpolates to get emission rates at intermediate speeds. The added emissions due to cold starts are calculated on a per vehicle trip basis and combined with emissions from highway system segments.

Fuel Consumption Analysis

Increases or decreases in highway use of motor fuel are estimated using a table of energy consumption rates as a function of speed for each mode. Speeds are in five mile per hour intervals, and the model interpolates for intermediate values.

3.0 Spreadsheet Inputs and Outputs

The Sketch-Planning Analysis Spreadsheet Model (SPASM) analyzes the effects of transportation actions on six modes of transportation: automobile, truck, carpool, local bus, express bus, and rail. It performs separate analyses of these actions for peak and off-peak periods defined by the model user. The spreadsheet model is configured as a single workbook, which consists of several worksheets. Spreadsheet inputs and outputs are presented on the following worksheets:

- **Unit Costs:** contains unit costs and other parameters for each of the five modes analyzed, as well as some general parameters needed by the spreadsheet model.
- **Impact Rates:** contains emission rates and energy consumption rates as a function of speed, as well as the added emissions for cold starts.
- **Agency Costs:** contains inputs needed to calculate annualized agency costs.
- **Facilities:** provides segment length, capacity, and free-flow speed for freeway, arterial, HOV, and rail system segments. These inputs are used to calculate line-haul speeds and in-vehicle travel times.
- **Demand Inputs:** contains peak and off-peak period inputs for the "Base Case" and "Improvement Case" on ridership, user costs, and access characteristics for each mode. The spreadsheet user indicates the number of person trips, vehicle occupancy, out-of-pocket cost, access shares, access distances, and wait time for each mode.
- **Outputs:** provides (1) user benefits, revenue transfers, and other impacts by mode and (2) a summary of annual benefits and costs. It is protected to prevent inadvertent changes.

These worksheets are described in the following sections. The spreadsheet model includes several additional worksheets on which intermediate impact calculations are performed. Those worksheets also are protected to prevent inadvertent changes.

Unit Costs Worksheet

The Unit Costs Worksheet is shown in Exhibit 2. General analysis parameters shown on this worksheet are:

- **Weekdays per year (excluding holidays):** used to expand analysis results for an average weekday to represent an entire year
- **HC, CO, and NOX cost per ton (dollars):** the values associated with reductions in pollutant emissions for hydrocarbons, carbon monoxide, and nitrogen oxides. These values are used in calculating the net benefits of the transportation actions under consideration.

Exhibit 2
Unit Costs

- Grams per ton: used to convert emissions in grams to emissions in tons
- Average speeds for auto, bus, and walk access to transit
- Added delay for buses on arterials (relative to autos) due to stopping to pick up and discharge passengers (in minutes per mile)
- The travel time exponent used to distribute traffic among parallel highway facilities. For example, a value of -4 would distribute traffic among facilities in proportion to the quantity t^{-4} where t is travel time
- An iteration control factor for traffic assignment. This factor determines the number of iterations necessary to achieve convergence in the traffic assignment process. It should always be greater than zero and less than one. A value close to 1 will result in quicker convergence. However, the assignment process may be unstable with a high value for the iteration factor. An initial default value of 0.1 is recommended for this variable. The spreadsheet user can then adjust it upwards or downwards to improve performance of the assignment process.

The Unit Costs Worksheet also provides unit costs and other analysis parameters for individual modes: auto (which includes light trucks used for personal transportation), truck, carpool, local bus, express bus, and rail. The analysis parameters are:

- Value of travel time (dollars per person hour): used for calculating user benefits due to time saving provided by the transportation actions under consideration. Separate values are input for in-vehicle travel time and for walk and wait time since empirical studies have shown that travelers generally find walk and wait time more onerous.
- Energy unit and BTUs per energy unit: used to convert energy savings for different modes to a common measure.
- User cost per energy unit (dollars): this is the out-of-pocket cost paid by transportation system users for gasoline, diesel fuel, or other forms of energy. This unit cost is usually zero for bus and rail transit, since transit energy costs are paid directly by the transit agency.
- Non-fuel user cost per vehicle mile (dollars): includes non-fuel motor vehicle operating costs such as oil, tires, repairs, and depreciation.
- Public agency cost per vehicle mile (dollars): the costs of operating transit service which vary with changes in bus or rail car miles, expressed on a per-vehicle mile basis. Key items include costs for drivers, fuel, and maintenance.
- External costs excluding emissions (dollars per trip and per vehicle mile): These inputs allow the users to include other external costs (in addition to pollution) which are not paid directly by transportation system users or public agencies. These might include incremental costs to employers (or others) of providing parking for motor vehicles
- Travel time elasticity: defined as the percentage change in travel demand due to a one percent increase in travel time. This elasticity is used to calculate the amount of travel induced by time savings due to transportation actions. If the demand inputs (discussed below) already include these effects, the elasticity should be set to zero.

- Passenger car equivalents: used to account for the fact that, on a per vehicle mile basis, trucks and buses have a greater impact on congestion than automobiles. For example, a PCE value of 2.0 for trucks would indicate that one vehicle mile by a truck has the same effect on congestion as two vehicle miles by a passenger car.

Impact Rates Worksheet

The impact rates worksheet is shown in Exhibit 3. This worksheet provides emission rates (in grams per vehicle mile) and energy consumption rates (using energy units defined on the unit costs worksheet) as a function of speed for automobiles, trucks, buses, and rail. The worksheet also provides added grams per cold start and the number of cold starts per vehicle trip during peak and off-peak periods. These inputs are used to calculate the added emissions due to cold starts on a per vehicle trip basis.

Exhibit 3 provides default emission rates derived for 1995 conditions. The rates in these tables were developed using outputs from EPA's MOBILE 5A model¹ and methodology presented in a February 9, 1993 letter on the "treatment of start emissions in TCM modeling" from Robert C. Dulla of Sierra Research to Philip Lorang of the U.S. Environmental Protection Agency.

EPA's MOBILE 5A model produces emission rates (grams per mile) as a function of speed for a VMT-weighted average of (1) cold-start, (2) stabilized, and (3) hot-start operations. According to the Sierra methodology, emissions for non-cold-start operations are calculated by setting the cold start VMT fraction equal to zero, the hot start VMT fraction equal to 0.479 and the stabilized VMT fraction equal to 0.521. The added emissions due to each cold start are calculated by subtracting the gram per mile value (at 26 mph) under hot start conditions from the gram per mile value (also at 26 mph) under cold start conditions, and multiplying the result by 3.59 miles.

¹MOBILE 5A was applied with the following assumptions:

- default tampering rates
- default annual mileage accumulation rates and registration distribution by age
- no anti-tampering program
- low altitude and no oxygenated fuels
- reformulated gasoline
- maximum temperature of 84 degrees
- minimum temperature of 60 degrees
- no inspection and maintenance program

Exhibit 3
Impact Rates

MOBILE 5A produces emission rates for light- and heavy-duty vehicles with gasoline and diesel-powered engines. In calculating the emission coefficients shown in the tables, "auto" and "carpool" coefficients are based on MOBILE emission rates for light-duty vehicles, "truck" coefficients are based on MOBILE coefficients for heavy-duty vehicles, and "bus" coefficients are based on MOBILE coefficients for heavy-duty diesel vehicles. MOBILE default VMT percentages by vehicle class² were used to combine emission rates for the various light-duty vehicle classes to represent "auto" and "carpool", and to combine emission rates for the various heavy-duty vehicle classes to represent "trucks".

The spreadsheet allows the user to specify the fraction of vehicle trips resulting in cold starts for the peak and off-peak periods. Venigalla, Miller and Chatterjee³ present a series of tables that can be used to develop this information. They used information from the Nationwide Passenger Transportation Survey to estimate the start modes (cold vs. hot) by trip purpose (home-based work, home-base other, and non-home-based), hour of the day, and urban area size class. For all trip purposes and urban area size classes combined, their data indicate that 60 percent of peak period trips and 56 percent of off-peak trips are cold starts.

The default energy consumption rates for automobiles and trucks are based on data from Hatano, Shirley, and Talago, and Palen⁴ on fuel consumption as a function of speed. The fuel consumption rates are undated to 1993 using fleet average fuel consumption rates provided in the Federal Highway Administration's *Highway Statistics*.

Agency Costs Worksheet

The agency costs worksheet (shown in Exhibits 4, 8, 12, 16, and 20) includes information on capital, operating, and maintenance costs to public agencies associated with the transportation improvements under consideration:

² The default percentages are as follows:

Light-duty gas vehicles	63.3%
Light-duty gas trucks	26.4%
Heavy-duty gas vehicles	3.1%
Light-duty diesel vehicles	0.4%
Light-duty diesel trucks	0.2%
Heavy-duty diesel vehicles	6.1%
Motorcycles	0.7%

³ Mohan Venigalla, Terry Miller, and Arun Chatterjee; "Start Modes of Trips for Mobile Source Emissions Modeling"; *Transportation Research Record 1432*; Transportation Research Board; 1995.

⁴ M.M. Hatano, E.C. Shirley, D. Talago, and J. Palen; *Energy and Transportation Systems*; Caltrans Report FHWA/CA/TL-83/08 for the Federal Highway Administration. These data are summarized in Louis F. Cohn, Roger L. Wayson, and Roswell; "Environmental and Energy Considerations"; Chapter 13 of the *Transportation Planning Handbook*; published by the Institute of Traffic Engineers (1992).

- Discount rate: in the analysis of public investments, a discount rate is used to make dollar-valued benefits and costs in different years comparable. A discount rate is necessary because benefits received and costs incurred in future years generally must be discounted to be comparable to benefits received and costs incurred today
- Capital cost (in thousands of dollars): capital costs of the transportation actions under consideration. The spreadsheet currently allows up to three capital cost items, but can easily be modified to include additional items.
- Midpoint of construction period and year of opening (in years): used to account for the fact that capital outlays frequently must be made well in advance of the time period during which they are useful. In the analysis, all capital costs are assumed to be incurred at the midpoint of the construction period.
- Useful life (years): the useful life of each capital cost item is used to convert one-time capital costs to an annualized basis.
- Other O & M costs (in thousands of dollars per year): includes changes in other operating and maintenance costs to public agencies that are not already included in public agency costs per vehicle mile for each mode (on the unit costs worksheet).

All dollar-valued spreadsheet inputs should be in constant dollars for a given year. Thus, at the outset, the spreadsheet user must select a single year for all dollar-valued inputs and, if necessary, apply the consumer price index (CPI) or some other price index to convert all dollar values to the selected year.

Facilities Worksheet

On the Facilities Worksheet (shown in Exhibits 5, 9, 13, 17, and 21), the model user specifies segment length, capacity, free-flow speed, and added delay (e.g., due to toll collection or ramp metering) for freeway, arterial, HOV, and rail system segments for the Base Case and an Improvement Case. These inputs are used to calculate line-haul speeds and in-vehicle travel times. The model user also can input a multiplier to be applied to external costs for each facility. This multiplier might be used to account for the differences in accident rates on different types of facilities.

Autos and trucks are assumed to use freeways and arterials. Local buses are assigned to arterials only. Carpools and express buses are assumed to use HOV lanes, as well as general purpose freeways and arterials. As currently implemented, the spreadsheet allows the user to define characteristics for up to three freeways, three arterials, one HOV facility, and one rail line.

The base case represents conditions if the transportation actions under consideration are not implemented, and the improvement case represents conditions if the actions are implemented. The spreadsheet model compares conditions with and without the actions to estimate their net benefits.

Demand Inputs

The demand inputs worksheet (shown in Exhibits 6, 10, 14, 18, and 22) includes peak and off-peak inputs for (1) a base case and (2) an improvement case. The peak period is assumed to be from 7:00 to 10:00 AM and from 4:00 to 7:00 PM. Peak period person trips include only those moving in the heavier direction

(e.g., toward the CBD during the AM peak and away from the CBD during the PM peak). Counter-peak person trips (e.g., away from the CBD during the AM peak) are included in the off-peak.

For each mode (auto, truck, carpool, bus, and rail), the inputs are as follows:

- Person trips per day: number of one-way person trips on an average weekday
- Vehicle occupancy: number of persons per vehicle
- Out-of-pocket cost per person trip: fares, tolls, and other costs to system users on a per person trip basis. Tolls that are levied on a per vehicle trip basis should be adjusted (using vehicle occupancy) so that they are expressed on a per person trip basis. The spreadsheet subtracts out-of-pocket costs for the Base Case from those for the Improvement Case, so that only the change in out-of-pocket cost is actually needed.
- Wait time per trip (minutes) includes walk, wait, and other components of travel time not included in in-vehicle time. Accurate estimates of excess time per trip are needed only if this time differs between the base case and improvement case. As with out-of-pocket cost, only the change in excess time is actually needed by the spreadsheet.
- Access mode fractions: the percentage of travelers walking, using auto, and using bus to access line-haul transit.
- Access distances: the distance in miles for each of the three access modes.

Outputs

The Outputs worksheet (shown in Exhibits 7, 11, 15, 19, and 23) provides daily impacts by mode on the following quantities:

- Person trips, with changes due to induced traffic specifically identified.
- User benefits
- Revenue transfers -- revenue transfers are increases in revenues to public agencies that occur as a result of increases in the out-of-pocket cost per person trip. User benefits are reduced as a result of increases in out-of-pocket costs per trip. Since these payments are transfers (not net increase in the cost of transportation to society as a whole), it is necessary to add these revenue transfers to user benefits in calculating net benefits (or costs) to society of the actions under consideration.
- BTUs (in millions)
- Emissions (in dollars)
- Other external costs (in dollars): these costs are calculated by applying the unit costs for “External Costs (excluding emissions)” to the change in vehicle miles and vehicle trips for each mode.

- Public vehicle operating costs: calculated by applying the “Public Agency Cost Per Vehicle Mile (\$)” unit cost from the unit costs worksheet to the change in vehicle miles.

The summary of annual benefits and costs shows the calculation of net benefits (or costs) of the actions under consideration. Net benefits are calculated by subtracting costs to public agencies and external costs from the sum of user benefits and revenue transfers.

A benefit/cost ratio is also calculated. The numerator of this ratio is annual user benefits plus revenue transfers minus the change in external costs. The denominator is annualized costs to public agencies.

4. Sample Applications

This chapter presents sample applications of the Sketch Planning Analysis Spreadsheet Model (SPASM) to seven alternatives in the I-15 Corridor in Salt Lake City, Utah:

- Construction of Light Rail Transit on Existing Railroad Right-of-Way
- Bus Service Expansion
- Highway Capacity Expansion
- Toll Collection on I-15
- Reversible HOV Lanes
- Ramp Metering
- Advanced Traveler Information System

For each of the seven alternatives, this chapter provides:

- A one page summary of the characteristics of the alternative to serve as the basis for spreadsheet inputs
- A printed copy of the Agency Costs worksheet
- A printed copy of the Facilities worksheet
- A printed copy of the Demand Inputs worksheet
- A printed copy of the Outputs worksheet

Light Rail Transit Alternative

- Capital cost of \$243,500,000 for guideway and vehicles. Construction begins in 1994 and the year of opening is 1998. The investment is assumed to have a useful life of 30 years.
- Person trips per day:

	Auto	Truck	Carpool	Bus	Rail
Peak	30,800	1,800	13,800	7,000	13,000
Off-Peak	117,000	6,000	2,400	7,000	13,000
Daily	147,800	7,800	16,200	14,000	26,000

- Light rail vehicle occupancy of 32 in peak and 14 in off-peak
- Light rail average trip length of 10 miles
- Light rail system speed of 30 miles per hour
- Light rail wait time of 5 minutes per trip (vs. 4 for Base Case bus)
- Fare increase from \$1.00 to \$1.25 for bus and light rail
- Light rail access mode split is 30% walk, 30% auto, and 40% bus
- Access distances are 0.4 miles for walk, 3 miles for auto, and 3 miles for bus

Exhibit 4
Agency Costs for Light Rail Transit

Exhibit 5
Facilities for Light Rail Transit

Exhibit 6
Demand Inputs for Light Rail Transit

Exhibit 7
Outputs for Light Rail Transit

Bus Service Expansion Alternative

- Capital cost of \$19,712,400 for 100 buses to be purchased in year of opening. The useful life of each bus is 10 years.
- Capital cost of \$9,727,800 for bus garage. Construction begins in 1994 and the year of opening is 1996. The useful life of the bus garage is 20 years.
- Person trips per day:

	Auto	Truck	Carpool	Bus	Rail
Peak	34,800	1,800	13,800	16,000	-
Off-Peak	121,000	6,000	2,400	16,000	-
Daily	155,800	7,800	16,200	32,000	-

- Bus occupancy is reduced to 26 in the peak and 12 in the off-peak (vs. 28 and 13 respectively in the Base Case)
- Wait time is reduced by 2 minutes per trip
- In-vehicle time reduced by 5 minutes due to less circuitous routings on arterials. This can be simulated by increasing the speed on arterials from 20 miles per hour to 24 miles per hour; i.e., $60 \text{ minutes per hour} \times 10 \text{ miles} \times (1/20 - 1/24) = 5 \text{ minutes}$.
- Walk distances are reduced by 0.1 miles on the average

Exhibit 8
Agency Costs for Bus Service Expansion

Exhibit 9
Facilities for Bus Service Expansion

Exhibit 10
Demand Inputs for Bus Service Expansion

Exhibit 11
Outputs for Bus Service Expansion

Highway Capacity Expansion Alternative

- Capital cost of \$39,072,000 for new lanes. Construction begins in 1994 and the year of opening is 1998. The useful life of these lanes is 30 years.
- Highway maintenance costs increase by \$1,136,400 for new facility (relative to old facility).
- The number of lanes is increased from 6 to 8. Capacity per lane is unchanged at 2,000 passenger car equivalents per hour per lane.
- Person trips are assumed to be unchanged from Base Case (prior to consideration of induced traffic).

Exhibit 12
Agency Costs for Highway Capacity Expansion

Exhibit 13
Facilities for Highway Capacity Expansion

Exhibit 14
Demand Inputs for Highway Capacity Expansion

Exhibit 15
Outputs for Highway Capacity Expansion

Toll Collection Alternative

- Capital cost of \$8,891,700 for toll collection facilities. Construction begins in 1994 and the year of opening is 1996. The useful life of these facilities is 15 years.
- Maintenance and operating cost of the toll collection facilities is \$1,854,400 per year.
- Person trips per day:

	Auto	Truck	Carpool	Bus	Rail
Peak	31,600	1,800	13,800	19,200	-
Off-Peak	122,600	6,000	2,400	19,200	-
Daily	154,200	7,800	16,200	38,400	-

- The toll is \$1.00 per vehicle trip for autos, trucks, and carpools.
- Auto occupancy is expected to increase from 1.05 to 1.15 in the peak period and from 1.16 to 1.3 in the off-peak period.
- Travel time is increased by 1 minute during the off-peak period and 5 minutes during the peak period due to toll collection.

Exhibit 16
Agency Costs for Toll Collection

Exhibit 17
Facilities for Toll Collection

Exhibit 18
Demand Inputs for Toll Collection

Exhibit 19
Outputs for Toll Collection

High Occupancy Vehicle Lanes

- Capital cost of \$41,690,600 for two 10-mile HOV lanes. Construction begins in 1994 and the year of opening is 1998. The useful life of these facilities is 30 years.
- Maintenance and operating cost of the HOV lanes is \$1,441,100 per year.
- Person trips per day:

	Auto	Truck	Carpool	Bus	Express Bus
Peak	25,780	1,800	18,000	4,548	16,272
Off-Peak	120,400	6,000	3,000	16,000	-
Daily	146,180	7,800	21,000	20,548	16,272

- Two lanes will be added, with a free-flow speed of 60 miles per hour and capacity of 2,100 passenger car equivalents per hour per lane.
- Bus occupancy will be increased to 32 during the peak and 15 during the off-peak period.

Exhibit 20
Agency Costs for HOV Lanes

Exhibit 21
Facilities for HOV Lanes

Exhibit 22
Demand Inputs for HOV Lanes

Exhibit 23
Outputs Costs for HOV Lanes

Ramp Metering Alternative

- Capital cost of \$9,053,200 for new ramp meters. Construction begins in 1995 and the year of opening is 1996. The useful life of these lanes is 20 years.
- Maintenance costs for ramp meters are \$521,200 per year.
- Mainline capacity on the freeway is increased by 15 percent due to ramp metering.
- Traffic entering each ramp meter location accounts for 5% of total freeway traffic.
- On average, ramp users incur a 30 second delay at on-ramps.
- Person trips are assumed to be unchanged from Base Case (prior to consideration of induced traffic).

Exhibit 24
Agency Costs for Ramp Metering

Exhibit 25
Facilities for Ramp Metering

Exhibit 26
Demand Inputs for Ramp Metering

Exhibit 27
Outputs for Ramp Metering

Advanced Traveler Information System for Transit

- Capital cost of \$1,733,500 for the ATIS. Construction begins in 1995 and the year of opening is 1996. The useful life of the system is 20 years.
- The cost of operating and maintaining the ATIS is \$562,500 per year.
- Person trips per day:

	Auto	Truck	Carpool	Bus	Rail
Peak	36,338	1,800	13,800	14,880	-
Off-Peak	122,490	6,000	2,400	14,880	-
Daily	158,828	7,800	16,200	29,760	-

- For 20 percent of bus riders, average wait time will be reduced by one minute, resulting in an average wait time reduction of 0.2 minutes.
- A sensitivity analysis was conducted in which the increase in bus ridership due to the ATIS was doubled. For the sensitivity test, person trips per day is as follows:

	Auto	Truck	Carpool	Bus	Rail
Peak	35,876	1,800	13,800	15,760	-
Off-Peak	121,979	6,000	2,400	15,760	-
Daily	157,855	7,800	16,200	31,520	-

Exhibit 28
Agency Costs for Advanced Traveler Information System

Exhibit 29
Facilities for Advanced Traveler Information System

Exhibit 30
Demand Inputs for Advanced Traveler Information System

Exhibit 31
Outputs for Advanced Traveler Information System

Exhibit 32
Demand Inputs for ATIS Sensitivity Analysis

Exhibit 33
Outputs for ATIS Sensitivity Analysis